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WASHINGTON STATE
ENERGY OFFICE

Savings from New Oil Furnaces:

A Study Conducted as part of Washington State's Oil Help Program

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A Study Conducted as part of Washington State's Oil Help Program

Prepared by:
WSEO Evaluation Team
Robert Davis, Principal Investigator

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Executive Summary

The Washington State Energy Office (WSEO) has been running the Oil Help program for three years. Originally operated as a loan program, Oil Help switched to rebates during the 1987 and 1988 fiscal years. During this time the program has been funded with oil overcharge funds and provides a rebate of 25 percent (up to $1,000) of the cost of a new oil furnace, flame retention burner, clock thermostat, or insulation. This popular program provided rebates to over 3,000 households in Washington during 1988 alone.

Rebates for oil furnace replacements made up over 70 percent of rebate funds, which totaled about $1.3 million. Controversy over the cost-effectiveness of new oil furnaces prompted Oil Help program managers to request a study of savings accruing to oil furnace replacements.

Prior to the study, WSEO had taken a conservative view based on the steady state efficiency statistics kept for the program. The average savings based solely on the change in steady state combustion efficiency for 787 furnaces was 16.3 percent. Fuel oil dealers, who benefited from increased furnace sales due to the program and who were the *de facto* main marketers of the program, argued that this number was too low and that average annual savings were more in the 25 to 30 percent range. The choice of savings figure had a direct bearing on the cost effectiveness of the program.

WSEO Evaluation started research in the summer of 1988 with the goal of including 100 new furnace households (with a control group of similar size) in the study. Our intention was to look at long-term oil consumption (at least two years before and after furnace replacement), comparing each household with itself over the two periods. We corrected for the effects of varying weather conditions and used a control group of cases served by the same dealers.

An occupant survey, conducted during July through September, was used to screen cases for changes in building occupancy and use during the study periods. We intended to use residences in both western and eastern Washington, but we were not able to obtain sufficient data from eastern Washington to include these cases in the study.

Because furnaces replaced under Oil Help were not installed until 1987 at the earliest (thus making it impossible to get at least two years of post-replacement consumption data), we used new furnace cases installed in 1984, 1985, and 1986 by some of the same oil dealers who participated in Oil Help. No Oil Help households were included in the study.

The final study group includes 43 households and a control group of 87 households. We anticipated considerable data attrition, but still fell well short of our target. The data do not constitute a statistical sample and we hesitate to generalize to the larger population of oil heated homes. The data do provide a reasonably sound estimate of savings which can be attained by installing a new oil furnace in western Washington.

Major Findings

- The median change in long-run oil usage for the households which replaced furnaces was 22.1 percent.
- Earlier evaluation of Oil Help showed that other heating energy conservation measures are better investments than a new oil furnace. This finding was based on an average estimated savings of 16.3 percent (based on change in steady state combustion efficiency) due to furnace replacement. The use of 22.1 percent savings does not change the results a great deal. The next table (taken from the interim impact study and included as Appendix E in this report) compares furnaces with the other measures installed under the Oil Help program.
- If an existing furnace has a reasonable chance of lasting for 10 years or more, and if it can be retrofitted with a high temperature combustion chamber, a new flame retention burner is a better investment than a new furnace. (The current Oil Help program has instituted quality control measures to ensure that flame retention burners are being installed only in furnaces with a useful life of 10 years or more.) As the table shows, (see following page) savings from the burner

replacement will be similar to those for entire furnace replacement at about one third of the cost, and the simple payback for the flame retention burner will be about 7 years rather than 19. Unless the furnace is near the end of its useful life or is inoperative, burner replacement is preferable to whole furnace replacement.

- Setback thermostats and insulation are also preferred measures. Although the average insulation payback is more than 10 years, this is a passive measure which generally has a useful lifetime of 20 years or more. Clock thermostats are easy to install, inexpensive, and last for at least 10 years. Because of the smaller average Oil Help rebates for these measures compared to furnace measures, more clients could be served by a program which limited or eliminated rebates for new furnaces.

Relative Economics of Home Heating ECMs
(Wet 'ern Washington)

Measure	Average Cost		Annual Average Savings	Simple Payback*	Expected** Useful Lifetime
New oil furnace	$1,964	(N=1,955)	22.1%	16.8 yrs	15 yrs
Flame ret. burner	$642	(N=1,041)	16.6%	7.3 yrs	15 yrs
Insulation	$1,137	(N=395)	17.6%	12.0 yrs	20-30 yrs
Clock thermostat	$94	(N=439)	10.0%	1.8 yrs	10-15 yrs

*Based on oil price of $0.85/gallon and average annual oil use of 625 gallons.
**Based on review of industry literature and oil dealer contacts.

Introduction

The Washington State Energy Office (WSEO) has been running the Oil Help program for three years. Originally operated as a loan program, Oil Help switched to rebates during the 1987 and 1988 fiscal years. During this time the program has been funded with oil overcharge funds and provides a rebate of 25 percent (up to $1,000) of the cost of a new oil furnace, flame retention burner, clock thermostat, or insulation. A separate report (Risman et al., 1989) evaluates the process of delivering this popular program, which provided rebates to over 3,000 households in Washington during 1988 alone.

Rebates for oil furnace replacements made up over 70 percent of rebate funds, which totaled about $1.3 million. Controversy over the cost effectiveness of new oil furnaces prompted Oil Help program managers to request a study of savings accruing to oil furnace replacements. Prior to the study, WSEO had taken a conservative view based on the steady state combustion efficiency statistics kept for the program; the average annual savings based-solely on the change in furnace steady state combustion efficiency for 787 households was 16.3 percent. Fuel oil dealers, who benefited from increased furnace sales due to the program and who were the *de facto* main marketers of the program, argued that this number was too low and that average savings were more in the 25 to 30 percent range. The choice of savings figure had a direct bearing on the cost effectiveness of the program. [1]

WSEO Evaluation started research in summer of 1988, with the goal of including 100 new furnace households (with a control group of similar size) in the study. Our intention was to look at long-term oil consumption (at least two years before and after furnace replacement), comparing each household *with itself* over the two periods. We corrected for the effects of varying weather conditions (employing the method used by Hirst (1981)), and used a control group of cases served by the same dealers. An occupant survey, conducted during July through September, was used to screen cases for changes in building occupancy and use during the study periods. We intended to use residences in both western and eastern Washington, but we were not able to obtain sufficient data from eastern Washington to include these cases in the study.

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The final study group consists of 43 households and a control group of 87 households. We anticipated considerable data attrition, but still fell well short of our target. The data do not constitute a statistical sample and we hesitate to generalize to the larger population of oil heated homes. The data do provide a reasonably precise estimate of savings which can be attained by installing a new oil furnace in western Washington.

The report begins with a review of related research. A discussion of research methodology, weather normalization procedure, data attrition, and important descriptive details follows. Changes in consumption for the new furnace and control groups are reported and are tested for significance. Finally, we discuss the implications of the results for the cost effectiveness of an oil furnace replacement.

Related Research

The oil heat literature is incomplete regarding furnaces. This was one reason WSEO undertook its

(1) WSEO Management decided to drop furnace replacements from the Oil Help program in fiscal year 1989. (This round of the program is called Cycle 2.) This was partially due to the uncertainty in furnace savings and partially due to the available program funding. Since only about 15 percent of the FY 1988 funding was available for rebates in FY 1989, the program would have only lasted about two months if furnaces were allowed in the program. This is because the average rebate for furnaces is considerably higher than the average rebates for other measures (about $500 vs. $180 for flame retention burners and about $250 for insulation measures).

study. Studies of oil heating equipment retrofits have focused mostly on either furnace tune-ups or on furnace retrofits such as vent dampers and new flame retention burners (FRBs). It was difficult to compare different studies because of data differences (sample size, method of measuring oil usage, variables measured (occupancy, alternate heating fuels, hot water fuel type), and so on). However, a review of the literature does show the range of savings for various oil heating system efficiency measures, and this research was a starting point for estimating savings from new furnaces.

A number of reports have been written on furnace tune-ups and other O&Ms. Witte and Kushler (1985) found that furnace tune-ups resulted in average annual savings of about 4 percent, as did the Massachusetts Audubon Society (Nadel, 1986).

There is another body of research which addresses savings due to installation of new flame retention burners. The most influential early work in this field was done by Brookhaven National Laboratory. A comprehensive treatment of burners is "Field Tests of Refit Equipment for Residential Oil-Fired Heating Systems" (Hoppe and Graves, 1982). Using a sample of 22 houses and no control group, the authors found median annual savings of 18 percent for hydronic boilers (some of which also provide domestic hot water) equipped with a new flame retention burner, 11 percent median savings for double setback thermostats installed on boilers with conventional (non-FRB) burners, and 11 percent median savings for forced-air furnaces equipped with new FRBs.

Brookhaven's research supported a linear correlation of heating oil usage with heating degree days (base 65°F). Of 22 houses used in their study, 20 had correlation coefficients greater than 0.98. A correlation coefficient of 1.0 means a perfect "straight-line" mapping of one variable onto another. Only one correlation coefficient was less than 0.90.

Brookhaven relied on oil delivery data to calculate savings and compared these savings with the savings calculated based solely on the change in measured furnace steady-state combustion efficiency. The oil usage comparison led them to conclude that roughly two-thirds of the total energy savings of an FRB is due to improvement in steady-state efficiency (that is, the efficiency of the burner during its firing cycle) and roughly one-third of the savings is due to a reduction in off-cycle losses (losses through vents, the furnace wall, etc.). Based on this theory, they multiplied the change in steady-state efficiency by the reciprocal of two-thirds, or 1.5, to get total fuel savings. As a conservatism, Brookhaven used a multiplier of 1.4 (instead of 1.5) to find total energy savings based on steady-state efficiency.

This 1.4 multiplier was used in other reports. An extensive study conducted in Philadelphia (USDOE, 1981) measured fuel savings from installation of a furnace package containing a new flame retention burner, a setback thermostat, and a furnace tune-up. Evaluators installed in-line oil flow meters to compare consumption before and after installation of the measures. The study included 200 homes with some low-income and elderly cases, and a matched control group was used. Average annual savings of 14.9 percent were measured with the flow meters. Evaluators used the 1.4 multiplier to get "total savings" of 20.9 percent. Flow meters were also used by the Massachusetts Audubon Society in their study of burner replacement (Nadel, et al., 1986). They found average savings of 17.9 percent for 11 homes (no multiplier used). A study (28 cases with control group) of Minnesota oil-heated homes (USDOE, 1981) which received new FRBs showed average savings of 22 percent based on change in steady–state efficiency when multiplied by 1.4.

Although the multiplier technique was used by a number of researchers, no other studies were found which concluded that reduced off-cycle losses could account for about one-third of energy savings. Because we were concerned with the viability of the multiplier, we were even more interested in conducting our own study. We hoped to determine whether savings from new furnaces would be in the range expected for FRB replacement, or if they would be significantly higher.

Research Methodology

The basic aim of the study is to estimate space heating fuel savings resulting from the installation of a new furnace. Two main sources of data were needed to determine this. The first was fuel oil deliveries for consumers who bought new furnaces and for a control group of oil users who did not buy new furnaces. As stated above, these consumers *are not* Oil Help participants; however, they are customers of five of the most active Oil Help dealers. The aim was not to constitute a probability sample, but to get a good number of cases from a survey of available data. Altogether, 469 sets of delivery data were collected.

The second set of data came from a telephone survey of all participants. The surveys (Appendix A) asked questions about changes in household use and occupancy, use of programmable timeclocks, thermostat settings, auxiliary heating fuel(s), and furnace maintenance. These data were used to compare the replacement and control groups and to exclude cases from the final consumption analysis which reported changes severe enough to affect oil usage significantly.

Working with fuel oil delivery data is difficult because of a number of factors. First, the fuel tank fill may be total or partial. Just as you would not get an accurate picture of the gasoline mileage of your car if you based it on partial fill-ups of your car's fuel tank, you would not get an accurate savings figure for a new furnace by basing conclusions on partial fuel oil tank fills. We were able to solve this problem by careful review of delivery records. Computerized record forms contained a spot where the delivery driver indicated a full or partial fill.

Related problems are "will call" delivery schedules (deliveries are often partial fills and occur irregularly) and customers who buy oil from more than one dealer. These pitfalls were avoided through careful review of the delivery sheets and a double check during the occupant survey.

Annual comparisons of consumption were not made. Instead, to smooth out inevitable irregularities in consumption patterns and to minimize inventory carryover effects (see below), long-run weather-adjusted consumption was calculated by taking delivered gallons over at least a two year period before and after replacement (for most cases) and dividing these totals by the accumulated monthly heating degree days (base 65^{o}) for the periods, as reported by the National Oceanic and Atmospheric Association for the appropriate weather station. Starting and ending delivery dates were chosen in the middle of the heating season (December and January) to further minimize carryover problems.

This weather normalization procedure is similar to that used in other oil heating studies (most notably Hirst and Talwar (1981)) and is the same method used by oil dealers (the reciprocal of the ratio obtained is the "k factor," in oil dealer parlance) in predicting oil deliveries. Hirst used fillup amounts from oil deliveries during the heating season (1 October through 30 April) and divided by the heating degree days for this period. We did largely the same thing but used multiple whole-year HDD totals (and all-year deliveries), since end-effects could be significant (that is, some of the oil delivered at the end of a heating season might be used after the end of that period) and because some people (especially the elderly) heat their homes during most of the year.

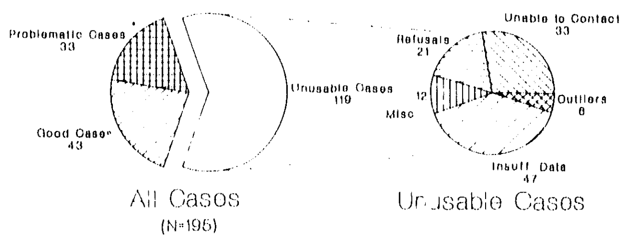
Aggregate changes in consumption were then calculated for new furnace and control groups. The three years during which all furnace replacements occurred were 1984-1986, so the consumption data analyzed came from the years 1982-1988.

Data Attrition

Although we did not aim to end up with a probability sample, an account of what data were originally available and what data were ultimately included in the final group can be useful for subsequent work on this subject. We started out with 469 cases (new furnace and controls) and ended up with a "clean" total of 130 (43 new furnace and 87 control) which we could use in our consumption analysis.

We start with the new furnace group. The reasons for exclusion are grouped into a few main categories (Figure 1):

Figure 1
New Furnace Group
Data Attrition



* Cases with significant structural and/or use changes

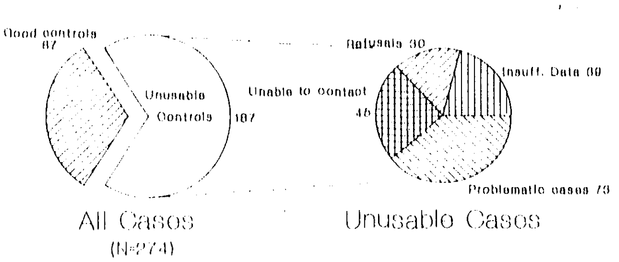
We started with 195 cases where furnaces were replaced and included 43 cases in the final analysis, a "capture" rate of 22 percent. Of those excluded, 33 were designated "problemmatic"; these households changed their usage patterns during the study period, the most common being change in household size of more than one member (10 cases) and installation of energy conservation measures (11 cases). The remainder of this group was made up of major structural remodels, houses which used additional heating fuels (wood, electricity), or a combination of several complicating factors. Average change in consumption for the 33 problemmatic changes was calculated to compare with the "clean" cases; this average change is noted in a subsequent section on savings.

Then there are the 119 cases designated as "unusable." About 40 percent of these fell out because of insufficient data. This group is made up mostly of houses with irregular or incomplete delivery records, or houses where usage fluctuated dramatically from year to year and no explanation could be found even after surveying the occupants. All 21 of the Spokane cases fell into this category because of limited data. The remainder of cases were excluded for the following reasons: the telephone number was incorrect, had been changed, or was disconnected, the occupant could not be reached after three attempts, the occupants had moved, the respondent refused to go through the interview, the house had been occupied for a short time (current occupants had lived there less than 5 years), or the heating equipment had been converted from oil to some other fuel.

Next we turn to the control group. In the initial data gathering, we looked for long-term customers (at least 5 years of continuous service) who had their furnaces cleaned and tuned annually. We chose cases on the basis of dealer (hence geographical distribution) and time period. That is, we wanted to provide a control group which had a distribution of oil usage data from the same time periods (within a month at either end) as the new furnace group *and* which was drawn from the same service territories. The initial control group was considerably larger than the initial replacement group: 274 cases versus 195 cases. Figure 2 classifies the control group.

A total of 73 control cases were designated "problemmatic"; this group was similar to the

Figure 2
Control Group Data Attrition



* Cases with significant structural and/or use changes

"problemmatic" new furnace group in terms of reasons for exclusion from the final analysis. Problemmatic controls were included in the "unusable" group because using them as a comparison group would not strengthen the analysis. (As noted above, change in consumption over time is calculated for "problemmatic" furnace *replacements*; however, this number should be regarded as a footnote rather than as a major finding.)

The final "good" control group was composed of 87 houses (a "capture" rate of 32%). The matching to the new furnace group was such that there were only three new furnace cases which could not be matched to control cases on the basis of oil delivery dates. In all other cases, we doubled up on matching (2 controls for each new furnace).

Selection bias was not analyzed in detail beyond the description of the primary reason for exclusion as detailed above. That is, the excluded cases were not analyzed for other correlation with other factors such as household size (number of occupants) and income.

Occupant Survey

The study did not allocate resources for field visits, and we consider self-reported household structural data (vintage, size, insulation levels, etc.) unreliable, so we do not know these data for the cases in the study. Because of the similarity in consumption between the replacement and control groups prior to the installation of new furnaces, (see Table 1), we assume a rough equivalence between the groups.

The occupant survey was the first means used to compare the new furnace group with the control group. Household data often collected in such surveys include type of heating equipment, household income and number of family members, energy consumption, and size and vintage of house.

As far as heating equipment goes, we know that nearly all of the new furnaces installed were of the same make, if not model, and that the air furnace technology has remained relatively static over the last several years (Carlander, 1989). (All new furnaces installed were of the forced air type except for four boilers.) The makes and models of the 43 furnaces replaced were so disparate that partitioning the data and/or tying savings to replacement of various models proved impracticable.

We collected data on thermostat settings and use of programable thermostats. About one quarter of the new furnace group reported changing their thermostat setting after buying a new furnace; the average change was -1° F. Other studies have shown that selfreported thermostat settings can be unreliable (Dinan, 1987; Vine, 1985). Therefore, we did not query control group participants about thermostat settings. About onequarter of the new furnace group reported use of a programable thermostat of some sort. A few people were not sure if they had such a thermostat. We controlled for this factor by including roughly the same proportion of cases in the control group which reported using a clock thermostat.

Data were collected on household size (number of full-time occupants), household income, and, of course, oil usage. The new furnace and control group were very similar in household size categories (Table 1), except for the largest households, where there were six controls with five occupants and no new furnace households with this many occupants. There were six new furnace cases which reported an occupancy change of one during the study period. Most commonly, this was due to a spouse's death and the survivor did not report changes in the use of the house after the change. We controlled for this change by including roughly the same proportion of cases in the control group which reported a change in occupancy of one person.

Table 1
Size of Household

Household Size	Replacement Freq.	(% of grp)	Control Freq.	(% of grp)
1	11	(26.2%)	16	(19.5%)
2	24	(57.1%)	49	(59.8%)
3	6	(14.3%)	11	(13.4%)
4	1	(2.4%)	0	
5	0		6	(7.3%)
No Response	1		5	
	N=42		N=82	

The control group's household income was shifted more to the high end than the new furnace group's. There were four new furnace cases with an annual income of less than $10,000 and only one control case with annual income less than $10,000. On the other side, just over half of the control group had an annual household income of over $25,000. A chisquare test showed the relationship between income and household size as significant at greater than the 1 percent level for the control group. That is, there is less than a 1 percent chance that the relationship between household size and income is due only to chance.

From these last two sets of data one might expect – all other things being equal beside household size and income – that the control group would use more oil than the new furnace group. In fact, groupwide statistics showed the new furnace and controls' oil usage to be very similar for the period before new furnaces were installed.

Pre-replacement oil usage for both new furnace and control groups (that is, consumption for the time before new furnaces were installed in the new furnace group, during the years 1982-1984, in most cases) was compared. Accumulated gallonage was divided by accumulated heating degree days to get a weather-adjusted consumption ratio. For an example, we can look at the first entry in the replacement spreadsheet (Appendix B); see below.

For this case, the monitored period covered one full heating season (1984-85) and parts of two others. This was done to get the flavor of pre-replacement oil usage. (A new furnace was installed in July 1986.) The same process was used for post-replacement data.

Control data were matched to the new furnace data by time period and oil dealer. That is, for the new furnace case shown above, there was at least one (and usually two) control case with the same oil delivery dates and geographic area. This was true for all but three of the new furnace. The comparison is shown in Table 2.

Case #	Replace Date	Occupancy Change	Timclk Use	Tstat Change	Previous Period (before replaced)	Raw Previous gallons	HDD Change	Previous gallons per change in HDD
ARI	07/23/86	No	No	0	01/05/83 - 01/03/86	2354.2	16624	0.142

Table 2
Comparison of Pre-Replacement Oil Usage (adjusted for weather)

Group	**Mean* gallons/HDD**	**Median gallons/HDD**	**Standard Deviation**
Replacement	0.148 (N=43)	0.135	0.065
Control	0.145 (N=87)	0.142	0.048

*Difference between means not significant at $p < 0.001$ for paired t-test (two-tailed).

Results for the New Furnace Group

We now compare each household's weather-adjusted oil usage *with itself* over a period spanning at least two heating seasons before the furnace was replaced and for as much time as possible after the furnace was replaced (usually two heating seasons). We then compare the new furnace group with the control group (in the final savings analysis). Figure 3 (see following page) shows the change in consumption plotted against the ratio of prereplacement consumption divided by prereplacement cumulative heating degree days.

Changes in consumption are widely dispersed. Some households apparently *increased* consumption after buying a new furnace. This could be due to many influences, including fuel oil price (see the discussion, below), household characteristics (envelope, appliances, internal gains, solar orientation, infiltration, etc.), furnace performance (although the survey established a regular maintenance record for all cases included in the final analysis), and other factors which we attempted to account for with the occupant survey and the control group.

There is undoubtedly some unexplained variation which the survey did not catch, but we were hesitant to throw out the "non-savers" since this is bad statistical practice. Values above and below Tukey inner fences (Tukey, 1977) were excluded; the final set of 43 was pared down from 45 with this procedure. The inner fence method excludes all values which are below or above a calculated value equal to + 1.5 times the difference between the 75th and 25th percentile values in the frequency distribution, respectively.

Figure 4 (see following page) is a cumulative distribution of changes in consumption for the new furnace group. This figure plots the cumulative percentage of cases in the new furnace group against the percentage reduction in long-term oil usage. We see that about 70 percent of the new furnace group reduced consumption. The other 30 percent falls left of the "break-even" line (drawn through 0).

Figure 5 (see following page) is another cumulative distribution graph. It compares pre-and post-replacement oil use. The graph shows how the new furnace group shifted its consumption to the left. (That is, that the group trend is what we should expect toward lower oil consumption.)

Median change in oil consumption is shown in Table 3. Mean change was not reported for two reasons: (1) a geometric mean should be used when dealing with percentage changes, and geometric means cannot be calculated for data with different signs; (2) the distribution of changes was not normally distributed and hence reporting means is misleading.

Table 3
Aggregate Oil Use Change for New Furnace Group (N=43)

Statistic	**Change in Consumption (%)**
Median	-12.3
Range	-40.4 == 38.5

Results for the Control Group

We use the same general approach in looking at the control group that we did for the replacement group. Outlier tests did not remove any data from the final set. A scatterplot of long-run change in consumption shows that the majority of cases increased consumption during the study period (see Figure 6).

Next we summarize the groupwide change in oil usage for the control group. The numbers show a median *increase* of 9.8 percent in long-run oil use.

Table 4
Aggregate Oil Use Change for Control Group (N=87)

Statistic	**Change in Consumption (%)**
Median	9.8
Range	-17.9 == 37.6

Figure 3
New Furnace Consumption Change

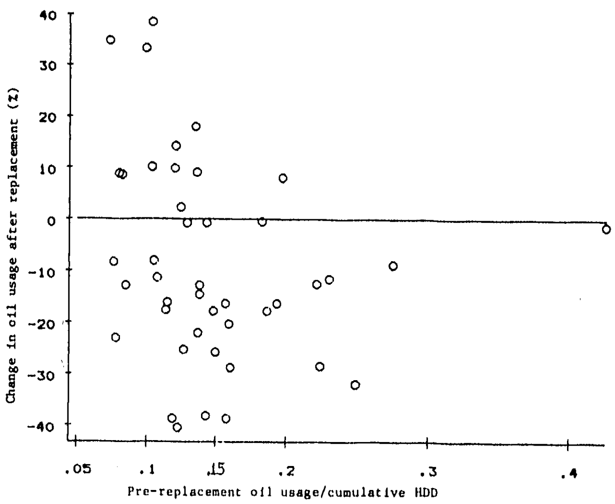


Figure 5
Before/After Comparison

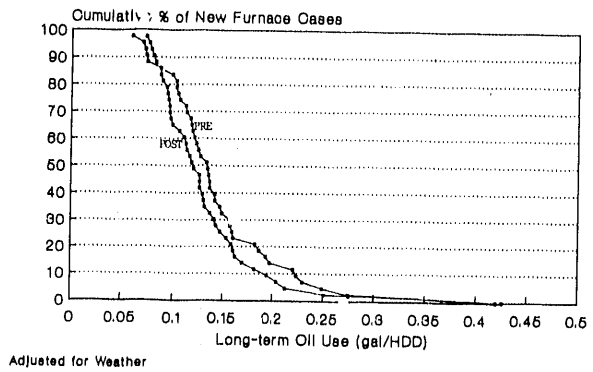


Figure 4
Cumulative Distribution of New Furnace Oil Use Reduction

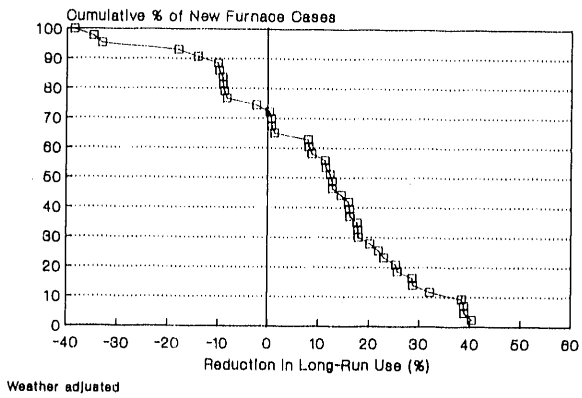
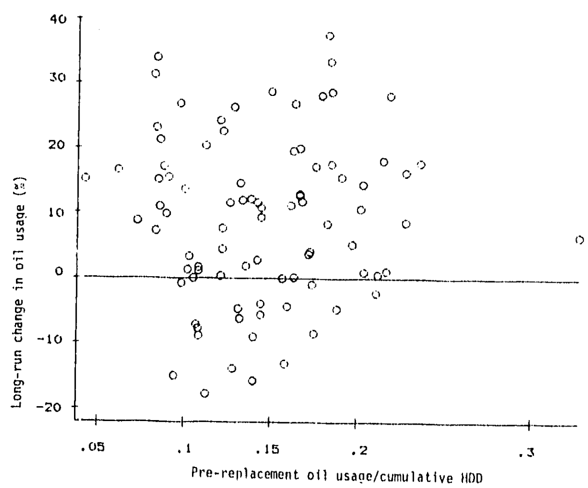


Figure 6
Control Group Consumption Changes

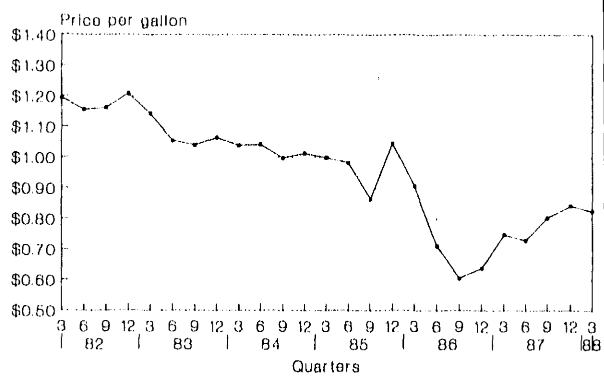


Considering that we screened for household changes which could have affected long-run oil usage with the occupant survey, why is it that our control group increased its consumption by 10 percent between the early 80s and late 80s? It is beyond the scope of this report to do more than guess, but our guess is a good one: the long-run price of oil has declined significantly since the early part of this decade, and consumers may be responding to this price change by relaxing their conservation ethic. This is analogous to what is happening with the recently increased speed limit and the revitalization of demand for luxury automobiles.

Frieden and Baker (1983), found that a 100 percent *increase* in fuel price results in about a 10 percent decrease in short-term (3-5 years) energy consumption. The price of fuel oil has gone the other way since the early 1980s, so an increase in fuel oil consumption makes sense.

Figure 7 shows that the nominal price of fuel oil declined by about one-third between March 1982 and March 1988. (This period brackets all possible date combinations used in the study.)

Figure 7
Washington Residential Fuel
Oil Price



Comparing the Replacement and Control Groups: Net Change

We now put the new furnace and control group numbers together to estimate savings from new furnaces. Before we do this, we should remember some of the descriptive data from above. Control group homes have higher incomes and larger households than replacement homes. We assume thermostat settings and the use of timeclocks are not a major factor in the savings estimate. And, most important, groupwide pre-replacement oil usage is not significantly different between new furnace and control cases.

A statistical test was carried out to determine if the differences in oil use between new furnace and control group over the monitoring period was due to anything other than random variation. A two sample Wilcox on RankSum test was used for this (Remington and Schork, 1985). This technique tests for the equality of medians between the two groups. It is a non-parametric test and is used instead of a t-test because the latter assumes normal distribution of consumption change.

The Rank-Sum test showed that there was less than one chance in a 100 that the difference in oil use between the new furnace and control group was due to chance. If the difference is not random and we continue to assume a pre-replacement equivalence between the groups, the difference in consumption must be due to installation of a new furnace.

If we assume further that the new furnace households responded like the control group to the historical decrease in oil prices over the last few years, we can find net savings from the program by adding the median decrease in new furnace oil consumption (12.3%) to the median increase in control group consumption (9.8%). This gives net median savings of 22.1 percent.

Two other statistics deserve mention. If we look at only the replacements for which usage declined (31 out of 43 cases), the average decline in consumption for this group was 18.3 percent; with the control group factored in, the decline is 27.3 percent. Next, if we add the 33 so-called "problemmatic" replacements (Appendix D) to the regular replacement group, the average decline in long-run consumption goes from 8.7 percent to 8.8 percent for all 76 cases. (Four outliers on the high side were removed from this combined group before analysis.) In general, the problemmatic replacements showed slightly higher average decline (9.0%) than the "good" replacements; we attribute this to the frequency of energy conservation measures (insulation, energy-efficient windows, etc.) installed by this group.

Conclusion

Based on a set of 43 households which bought new oil-fired furnaces in the mid 1980s in western Washington, the median change in long-run oil usage for these furnaces was 22.1 percent. Earlier work by this author (Appendix E) showed that other heating energy conservation measures were better investments than a new oil furnace. This finding was based on an average savings of 16.3 percent from installation of a new oil furnace. The use of 22.1 percent savings figure does not change the results a great deal. Table 5 compares furnaces with the other measures installed under the Oil Help program.

If an existing furnace has a reasonable chance of lasting for ten years or more, and if it can be retrofitted with a high temperature combustion chamber, a new flame retention burner is a better investment than a new furnace. As the table shows, savings from the burner replacement will be similar to those for entire furnace replacement at about one-third of the cost, and the simple payback for the flame retention burner will be about 7 years rather than 20. Unless the furnace is near the end of its useful life or is inoperative, burner replacement is preferable to whole furnace replacement. The payback calculation for the furnace does not include annual maintenance costs or burner replacement cost. (Replacement is likely after 10 years of operation.) Current Oil Help practice is to inspect furnaces which are candidates for new FRBs to ensure the furnace has an estimated useful life of at least ten years.

Night setback thermostats and insulation are also preferred measures. The current Oil Help program (Cycle 2) is stressing these measures because of their long-term benefits, limited operations and maintenance requirements, and favorable paybacks. Because of the smaller average rebates for these measures compared to new furnace rebates, relatively more people are being served with relatively limited rebate funds. Through June 1989, 814 households participated in Cycle 2 of the program. Using the same savings assumptions as shown in Table 5, Cycle 2's programmatic simple payback is 10.8 years, which is much shorter than the expected lifetime of any of these measures. In Cycle 2, 58 percent of participating houses had furnace measures installed and the rest had insulation installed.

Table 5
Relative Economics of Home Heating ECMs

Measure	Average Cost		Annual Average Savings	Simple* Payback	Expected** Useful Lifetime
New oil furnace	$1,964	(N=1,955)	22.1%***	16.7 yrs	15 years
Flame ret. burner	$642	(N=1,041)	16.6%	7.3 yrs	15 years
Insulation	$1,137	(N=395)	17.6%	12.0 yrs	20-30 years
Clock thermostat	$94	(N=439)	10.0%	1.8 yrs	10-15 years

*Assumes fuel oil price of $0.85/gallon and average annual oil usage of 625 gallons.
**Based on review of industry literature and oil dealer contacts.
***Median value

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Appendix A

Oil Help Furnace Replacement Study

Occupant Survey

July 28, 1988

Name______________________________ Oil Dealer______________________________

Date furnace purchased______________________

Status (replacement or control)______________________________

Date/Time______________________ 1st try________________

2nd try________________

Hello, this is __________ from the Washington State Energy Office, calling on behalf of _____________. In cooperation with oil dealers around the state, we are conducting a short survey of new furnace owners which will help us figure out how much new furnaces reduce oil usage. All information you provide is strictly confidential. Do you have 5 minutes to answer a few questions? (If not, set an appointment immediately for a call-back.)

Good call-back date/time____

____

Screening Questions

A. Our records show that you purchased a furnace in ______________________________.

Is this correct?

___Yes ___No (If NO, ask once again to confirm we have the wrong person, thank them, and end interview.)

B. Over the past few years, have you bought all of your oil from _____________, or have you bought oil from more than one dealer?

___one dealer ___more than one dealer

(If **more than one dealer**, end interview by saying, "The interview is over. To simplify research, our study will only include households which have bought oil from one dealer during the study period. Thank you.")

C. When your oil tank is filled, is it filled to the top, or do you call in and ask for a set amount (say 50 or 100 gallons)?

___fill

___will call

(If **will call**, end interview by saying, "The interview is over. We need to use households where the tank is filled to the top so that we can know what total consumption has been. Thank you.")

D. Have you lived in this home continuously for the last five years?

___Yes ___No (If **NO**, stop the interview, and say, "Our study will include households which have lived in a home for five years or more. Thank you for your participation.")

Occupancy/Use Changes

1. How many people live in your household? _____

2. In the past few years, has the total number of people in your home increased or decreased?

   ___No

   Yes (what are the changes and when did they occur?)________________________________

   ____

   ____

3. Has the pattern of home occupancy changed substantially in the past few years? For example, are you or other members of your household spending more or less time at home than you have in the past?

   __No
   Yes (what are the changes and when did they occur?)________________________________

   ____

   ____

   ____

4. Over the past few years during the heating season (September - May), have you or other members of the household taken vacations of more than one month during the past five years, or has your house been vacant for a month or more for any other reason?

   ___No

   Yes (when were these periods and how long?)

   ____

   ____

   ____

5. Has there been any period in the last few years where the furnace was off for a week or more during the heating season because of equipment malfunction?

   ___No

   Yes (what happened, when and how long did it last?)________________________________

   ____

   ____

   ____

6. Has the heated area of the home increased or decreased?
(That is, do you now heat more or fewer rooms than in the past, or have you done extensive remodeling in the past few years?)

___No

Yes (what are the changes and when did they occur?)______________________________

____

____

Energy Management

The next few questions concern energy management in your home.

7. Compared to when you had your old furnace, do you keep your thermostat higher, lower, or the same than before you replaced the furnace?

Higher (how much?) ___________
Lower (how much?)___________
The same_______________

8. Does your furnace have a time clock which can turn the furnace off when you're asleep or not at home?

___No
___Yes

9. Do you use the time clock?

___No
___Yes

10. Have you installed any weatherization measures in your home in the past few years (insulation, windows)?

___No
Yes (what are the measures and when where they installed?)______________________________

____

____

11. Have you used another source of heat besides oil (for example, wood or electricity) in the past few years? If yes, what percentage of your heating needs would you say are met by this other source?

___No
Yes (what type and what % of total needs met)______________________________

____

____

12. Does your furnace receive regular maintenance service (at least once a year?) (This includes filter and nozzle replacement, general cleaning, and adjustment.)

____No ____Yes

The next question is optional. We'd appreciate your input so that we can get a good profile of the group of people responding to the survey.

13. What was your household income last year, before taxes?

____< $10,000
____between $10,000 and $15,000
____between $15,000 and $20,000
____between $20,000 and $25,000
____over $25,000

That is the end of the survey. Thank you for your cooperation.

Oil Help Furnace Replacement Study

Occupant Survey - Control Cases

August 8, 1988

Name______________________________ Oil Dealer______________________________________

Date/Time ______________1st try____________________
______________2nd try____________________
______________3rd try____________________

Hello, this is _____________ from the Washington State Energy Office, calling on behalf of _____________. In cooperation with oil dealers around the state, we are conducting a study which will help us figure out how much new furnaces reduce oil usage. As part of this study, we are interviewing people who heat with oil. The information you provide will be used to calculate oil savings and is strictly confidential. Do you have 5 minutes to answer a few questions? (If not, set an appointment immediately for a call-back.)

Good call-back date/time_________________________________

Screening Questions

A. Over the past few years, have you bought all of your oil from __________, or have you bought oil from more than one dealer?

____one dealer ____more than one dealer

(If **more than one dealer**, end interview by saying, "The interview is over. To simplify research, our study will only include households which have bought oil from one dealer during the study period. Thank you.")

B. Have you kept your current residence for the last five years?

___Yes ___ No (If **NO**, stop the interview, and say, "Our study will include households which have lived in a home for five years or more. Thank you for your participation.")

Occupancy/Use C..anges

1. How many people lived in your household? _____

2. In the past few years, has the total number of people in your home increased or decreased?

___No
Yes (what are the changes and when did they occur?)_____________________________________

____

____

3. Has the pattern of home occupancy changed substantially in the past few years? For example, are you or other members of your household spending more or less time at home than you have in the past?

___No
Yes (what are the changes and when did they occur?)________________________________

____

____

4. Over the past few years during the heating season (September - May), have you or other members of the household taken vacations of more than one month during the past five years, or has your house been vacant for a month or more for any other reason?

___No
Yes (when were these periods and how long?)________________________________

____

____

5. Has there been any period in the last few years where the furnace was off for a week or more during the heating season because of equipment malfunction?

___No
Yes (what happened, when and how long did it last?)________________________________

____

____

6. Has the heated area of the home increased or decreased?
(That is, do you now heat more or fewer rooms than in the past, or have you done extensive remodeling in the past few years?)

___No
Yes (what are the changes and when did they occur?)________________________________

____

____

Energy Management

7. Does your furnace have a time clock which can turn the furnace off when you're asleep or not at home?

___No
___Yes

8. Do you use the time clock?

___No
___Yes

9. Have you installed any weatherization measures in your home in the past few years (insulation, windows?)?

___No
Yes (what are the measures and when were they installed?)____

____

____

10. Have you used another source of heat besides oil (for example, wood or electricity) in the past few years? If yes, what percentage of your heating needs would you say are met by this other sources?

___No
Yes (what type and what % of total needs met)____

____

____

11. Does your furnace receive regular maintenance service (at least once a year?) (This includes filter and nozzle replacement, general cleaning, and adjustment.)

___No ___Yes

The next question is optional. We'd appreciate your input so that we can get a good profile of the group of people responding to the survey.

12. What was your household income last year, before taxes?

____< $10,000
____between $10,000 and $15,000
____between $15,000 and $20,000
____between $20,000 and $25,000
____over $25,000

That is the end of the survey. Thank you for your cooperation.

Appendix B

NEW FURNACE CASES

NEW FURNACE CASES

CASE #	REPLACE DATE	OCCUPANCY CHANGE	TIMELY USE	TSTAT CHANGE	PREVIOUS PERIOD (before replaced)	RAW PREVIOUS gallons	HDD Change	PRE gallons per change in HDD	POST PERIOD (after replaced)	RAW POST gallons	HDD Change	POST gallons per change in HDD	CHANGE (%)
AP1	07/23/86	NO	NO	0	01/05/83 - 01/03/86	2354.2	16624	0.142	12/16/86 - 02/18/88	561.9	6438	0.087	-38.37
AP10	08/15/85	YES		0	11/02/84 - 02/19/85	817.9	2980	0.275	11/27/85 - 03/01/88	[illegible]	12494	0.251	-8.72
AP2	10/14/86	NO	YES	0	11/21/84 - 03/05/86	1989.1	8647	0.230	01/22/87 - 02/02/88	[illegible]	5031	0.204	-11.49
AP6	07/14/86	NO	-	0	12/12/84 - 02/28/86	1267.1	7989	0.159	01/14/87 02/01/88	637.1	5031	0.127	-20.16
AP7	04/15/85	NO	YES	0	11/17/82 - 01/28/85	2792.4	12623	0.221	10/29/85 - 12/28/87	2352.4	12131	0.194	-12.34
AP8	02/14/85	YES	YES	0	10/20/82 - 11/16/84	842.4	11037	0.076	11/23/85 - 12/28/87	803.0	11451	0.070	-8.12
AP9	12/30/84	NO	-	0	01/21/82 - 03/23/84	1209.9	11770	0.103	02/01/85 - 12/14/87	1687.8	14928	0.113	9.99
CP1	12/16/85	NO	NO	0	11/15/82 - 01/27/84	729.1	5336	0.137	01/10/86 - 03/15/88	1087.1	9313	0.117	-14.57
CP2	03/15/84	NO	-	0	12/31/82 - 01/02/84	512.2	4072	0.126	12/21/85 - 02/12/88	861.2	3176	0.094	-25.39
CP3	10/15/85	NO	YES	0	11/15/82 - 02/06/84	1059.4	5823	0.182	01/07/86 - 02/10/88	1590.8	8771	0.181	-0.31
CP4	05/20/86	NO	DK	0	11/30/84 - 01/21/86	2705.1	6350	0.426	11/12/86 - 03/04/88	2613.9	6228	0.420	-1.30
CP5	02/20/86	NO	-	0	11/20/84 - 01/03/86	1369.4	6124	0.224	03/27/86 - 03/17/88	1271.1	7968	0.160	-28.66
CP6	05/20/85	NO	-	0	12/04/82 - 02/03/84	803.1	5383	0.149	12/14/85 - 02/24/88	1065.0	9614	0.111	-25.75
OP1	01/22/85	NO	DK	3	01/27/83 - 11/14/84	1289.0	6940	0.186	11/29/85 - 03/23/88	1612.5	10571	0.153	-17.88
OP4	03/26/86	NO	-	-3	11/22/83 - 12/26/85	1407.0	10464	0.134	11/25/86 - 03/28/88	924.2	5832	0.158	17.86
OP6	01/15/85	NO	-	0	01/24/83 - 03/29/84	767.0	5207	0.147	11/29/85 - 03/14/88	1259.7	10402	0.121	-17.78
OP7	10/15/85	NO	-	0	11/12/82 - 02/05/85	2039.0	10556	0.193	01/10/86 - 02/17/88	1428.2	8822	0.162	-16.19
PP1	10/02/84	NO	-	-2	03/04/83 - 03/15/84	656.4	4180	0.157	01/31/85 - 01/13/88	1207.8	12571	0.096	-38.82
PP10	09/06/85	NO	YES	0	02/23/83 - 02/07/85	1682.9	8553	0.197	12/12/85 - 03/10/88	2106.8	9902	0.213	8.13
PP11	04/01/85	NO	-	0	02/02/83 - 12/14/84	583.7	7526	0.078	11/30/85 - 01/12/88	541.9	9071	0.060	-22.97
PP12	09/25/85	YES	-	0	02/09/83 - 02/15/85	1232.2	9018	0.137	12/03/85 - 01/07/88	1053.7	8843	0.119	-12.80
PP13	02/15/86	YES	YES	0	01/01/83 - 02/02/85	1332.0	9355	0.142	02/20/86 - 02/25/88	1153.9	8163	0.141	-0.72
PP16	09/03/86	NO	-	0	02/10/84 - 02/22/86	1457.4	9352	0.156	02/05/87 - 03/11/88	600.6	4603	0.130	-16.27
PP2	03/25/86	NO	-	0	01/20/83 - 01/28/86	1645.8	13834	0.119	11/11/86 - 01/29/88	730.2	5594	0.131	9.73
PP20	09/12/86	NO	-	-4	02/14/83 - 03/11/86	1929.1	14224	0.136	01/05/87 - 01/23/88	464.8	4388	0.106	-21.89
PP21	09/09/86	NO	-	-2	03/17/83 - 01/14/86	1031.0	12639	0.082	12/17/86 - 03/28/88	533.8	6022	0.089	8.66
PP3	01/09/86	NO	-	-2	11/15/84 - 12/05/85	1376.5	5524	0.249	02/24/86 - 02/05/88	1297.4	7667	0.169	-32.09
PP4	06/25/86	NO	YES	0	02/10/83 - 01/22/86	1379.6	13350	0.103	02/04/87 - 02/08/88	561.6	3925	0.143	38.46
PP5	06/13/86	NO	-	0	01/03/83 - 01/06/86	1710.1	13742	0.124	11/20/86 - 02/29/88	762.8	5994	0.127	2.27
PP6	05/12/86	NO	-	2	01/06/83 - 03/04/86	1812.9	14820	0.122	10/27/86 - 01/27/88	417.5	5728	0.073	-40.41
PP7	11/15/84	NO	-	0	03/09/83 - 04/12/84	499.2	4652	0.107	01/26/85 - 01/06/88	1193.6	12546	0.095	-11.35
PP8	08/30/84	NO	-	0	12/02/83 - 03/14/84	357.6	2231	0.160	01/03/85 - 02/02/88	1566.4	13725	0.114	-28.81
PP9	03/01/85	NO	-	0	01/13/83 - 02/11/85	1069.8	9393	0.114	11/13/85 - 01/12/88	914.7	9557	0.096	-15.97
WP1	11/19/85	NO	-	0	03/04/82 - 02/06/85	1536.3	15536	0.099	12/24/85 - 01/16/88	1434.0	10898	0.132	33.06
WP2	11/27/85	NO	-	0	02/13/82 - 03/18/85	1792.2	17020	0.105	12/24/85 - 01/19/88	1062.1	10965	0.097	-8.01
WP3	03/07/86	NO	-	0	12/13/82 - 12/20/85	2148.8	16762	0.128	12/06/86 - 03/24/88	970.8	7626	0.127	-0.70
WP4	01/22/86	NO	-	0	12/28/84 - 12/02/85	807.5	5982	0.135	02/07/86 - 02/26/88	1589.8	10803	0.147	9.02
WP5	07/18/85	NO	YES	2	12/08/83 - 03/12/85	977.8	8139	0.120	12/10/85 - 03/18/88	1748.7	12763	0.137	14.04
WP6	07/31/86	NO	-	-4	12/15/82 - 02/21/86	2058.8	18292	0.113	11/19/86 - 02/22/88	685.2	7393	0.093	-17.65
WP8	11/30/86	NO	-	0	03/04/85 - 03/17/86	705.2	5979	0.118	01/26/87 - 03/08/88	431.1	5981	0.072	-38.90
WP10	07/17/85	YES	-	0	01/12/84 - 01/31/85	486.3	6096	0.080	11/11/85 - 03/19/88	1186.3	13647	0.087	8.97
WP11	10/15/84	YES	-	0	01/06/82 - 12/30/83	762.2	10426	0.073	12/12/84 - 02/17/88	1779.3	18062	0.099	34.75
WP12	09/30/86	YES	-	0	10/29/84 - 02/24/86	761.2	8942	0.085	12/10/86 - 01/15/88	442.1	5956	0.074	-12.80

Appendix B (Cont'd.)

CONTROL DATA

CASE #	[illegible]	[illegible]	PERIOD	PREVIOUS gallons	Change	per change in HDD	PERIOD	POST gallons	Change	per change in HDD	CHANGE (%)
RL1	YES	-	11/22/82 - 11/23/84	653.0	10518	0.062	11/05/85 - 01/05/88	874.9	12089	0.072	16.57
RL1*	YES		11/23/84 - 01/07/86	680.3	7270	0.094	01/09/87 - 03/22/88	533.6	6719	0.079	-15.13
RL2	NO	-	11/14/84 - 03/06/86	1060.8	8783	0.121	01/31/87 - 02/18/88	662.9	5470	0.121	0.35
RL3	NO	YES	12/21/84 - 02/26/86	1073.7	7674	0.140	12/09/86 - 03/24/88	962.8	7570	0.127	-9.10
RL4	NO	-	12/20/82 - 02/01/85	1537.2	11746	0.131	12/05/85 - 02/17/88	1526.7	12258	0.125	-4.83
RL4*	NO	-	12/20/82 - 02/24/86	2402.8	18189	0.132	12/29/86 - 02/17/88	770.8	6230	0.124	-6.34
RL5	NO	-	11/22/82 - 02/07/85	1055.5	12682	0.083	10/28/85 - 12/22/87	1063.3	11927	0.089	7.12
RL5*	NO	-	01/18/83 - 02/12/86	1411.4	17212	0.082	12/19/86 - 02/05/88	591.1	5489	0.108	31.32
RC6	NO	YES	11/13/84 - 01/17/86	1759.9	7707	0.228	01/13/87 - 02/12/88	1532.4	5776	0.265	16.18
RC6*	NO	YES	11/13/84 - 03/25/85	759.7	3532	0.215	12/11/85 - 02/12/88	3040.6	11967	0.254	18.14
RC7	NO	-	03/19/82 - 04/02/84	2074.8	10554	0.197	01/09/85 - 01/08/88	3358.6	16249	0.207	5.14
RC7*	NO	-	12/15/82 - 01/09/85	2293.1	11243	0.204	12/17/85 - 01/08/88	2244.6	10916	0.206	0.82
RC7**	NO	-	10/29/84 - 03/19/85	784.8	3719	0.211	12/17/85 - 01/06/88	2244.6	10891	0.206	-2.33
RL8	NO	-	12/10/82 - 02/07/85	1008.6	12206	0.083	11/15/85 - 01/04/88	1197.5	11773	0.102	23.09
RL8*	NO	-	12/10/82 - 01/07/86	1439.4	17323	0.083	10/24/86 - 03/07/88	910.8	8184	0.111	33.93
RL10	NO	YES	11/07/84 - 03/01/85	299.3	3077	0.097	12/06/85 - 02/17/88	1509.7	12229	0.123	26.91
RL10*	NO	YES	11/07/84 - 01/24/86	815.4	7294	0.112	01/05/87 - 02/17/88	820.9	6100	0.135	20.38
OR3	NO	-	12/30/83 - 11/29/85	1533.0	8783	0.175	11/28/86 - 03/18/88	992.8	6212	0.160	-8.43
OR6	NO	YES	12/23/83 - 11/25/85	2030.0	8837	0.236	12/02/86 - 03/03/88	1620.1	5822	0.278	17.67
OR9	NO	-	12/01/83 - 12/12/85	1886.0	9965	0.189	11/18/86 - 03/18/88	1148.2	6368	0.180	-4.73
OR10	NO	-	01/25/83 - 12/31/84	975.0	8092	0.120	12/03/85 - 03/02/88	1470.6	9828	0.150	24.19
OR10*	NO	-	11/18/82 - 12/31/84	1161.0	9510	0.122	12/05/85 - 03/02/88	1470.6	9828	0.150	22.58
OR11	NO	YES	01/25/83 - 12/18/84	1302.0	7729	0.168	12/20/85 - 02/24/88	1774.8	9427	0.188	11.77
OR12	NO	-	11/30/82 - 01/02/85	1611.0	9297	0.173	01/27/86 - 03/01/88	1569.7	8700	0.180	4.12
OR12*	NO	-	01/24/83 - 11/06/84	1178.0	6841	0.172	12/13/85 - 03/01/88	1732.7	9717	0.178	3.56
OR13	NO	YES	02/02/83 - 12/31/84	2614.0	7975	0.328	12/22/86 - 03/17/88	1981.0	5674	0.349	6.51
OR14	NO	-	02/11/83 - 11/26/84	1276.0	6891	0.185	12/03/85 - 03/18/88	2244.9	10319	0.218	17.49
OR1	YES	-	10/11/82 - 02/07/84	641.0	6395	0.100	12/27/85 - 03/16/88	1098.1	9649	0.114	13.55
OR6*	NO	YES	11/15/82 - 02/23/84	1350.0	6156	0.219	11/25/85 - 03/03/88	2883.0	10252	0.281	28.23
OR8	YES	-	11/12/82 - 01/11/84	1224.0	5358	0.228	01/10/86 - 03/04/88	2259.1	9105	0.248	8.61
OR11*	NO	YES	10/06/82 - 01/11/84	982.0	5891	0.167	12/20/85 - 02/24/88	1774.8	9432	0.188	12.88
OR14	NO	-	10/07/82 - 01/31/84	1326.0	6109	0.217	01/16/86 - 03/18/88	2030.9	9262	0.219	1.03
RL9	YES	-	11/07/83 - 04/19/84	350.7	3095	0.113	12/06/84 - 01/09/88	1296.7	13934	0.093	-17.86
RL9*	YES	-	01/23/84 - 01/04/86	785.4	9211	0.085	02/21/87 - 04/20/88	468.3	4947	0.095	11.03
RC9**	YES	-	01/23/84 - 01/04/86	785.4	9211	0.085	04/08/86 - 01/09/88	639.4	6186	0.103	21.22
RC9***	YES	-	12/06/84 - 01/04/86	508.0	5867	0.087	04/08/86 - 04/20/88	818.6	8077	0.101	17.05
RC10	NO	DK	11/18/83 - 04/19/84	624.8	2951	0.212	01/23/85 - 01/27/88	2877.5	13518	0.213	0.55
RC10*	NO	DK	02/10/84 - 02/12/86	1787.4	9647	0.185	01/27/87 - 03/08/88	1124.6	4716	0.238	28.71
RC10**	NO	DK	02/10/84 - 11/13/85	1377.5	7493	0.184	02/12/86 - 01/27/88	1895.7	7728	0.245	33.44
RC10***	NO	DK	12/15/84 - 02/12/86	1168.1	6384	0.183	04/25/86 - 03/08/88	1852.9	7360	0.252	37.60
RC11	NO	-	01/20/83 - 02/01/85	1286.8	8964	0.144	02/22/86 - 02/16/88	1241.3	7920	0.157	9.19
RC11*	NO	-	01/20/83 - 12/16/85	1830.8	12878	0.142	12/02/86 - 02/16/88	881.4	5557	0.159	11.58
RC11**	NO	-	01/20/83 - 02/01/85	1286.8	8964	0.144	12/16/85 - 02/16/88	1493.2	9385	0.159	10.84
RC11***	NO	-	01/25/84 - 12/16/85	1207.7	7684	0.157	02/22/86 - 02/16/88	1241.3	7899	0.157	-0.02
RC12	NO	-	01/07/83 - 02/06/85	1148.9	9090	0.126	03/07/86 - 02/10/88	1038.6	7366	0.141	11.56
RC12*	NO	-	03/10/83 - 04/30/84	585.9	4078	0.144	02/06/85 - 02/10/88	1748.5	12913	0.135	-5.75
RC12**	NO	-	11/12/84 - 01/15/86	868.8	6575	0.132	03/07/86 - 04/11/88	1190.2	7867	0.151	14.50
RC12***	NO	-	03/10/83 - 01/15/86	1584.4	11451	0.138	11/20/86 - 04/11/88	945.4	6101	0.155	11.99
RC13	NO	-	03/01/83 - 03/09/84	386.5	4318	0.090	02/04/85 - 04/25/88	1411.7	13650	0.103	15.53
RC14	NO	-	01/13/83 - 12/21/85	2439.0	12066	0.202	12/18/86 - 02/04/88	1109.6	4965	0.223	10.56
RL14*	NO	-	01/13/83 - 02/28/85	1793.7	8826	0.203	12/21/85 - 04/09/88	2239.3	9629	0.233	14.43
RC14**	NO	-	03/03/83 - 01/17/86	2392.5	12504	0.191	12/18/86 - 04/09/88	1330.8	6021	0.221	15.52
RC14***	NO	-	01/28/84 - 02/28/85	952.6	5333	0.179	12/18/86 - 12/26/87	922.6	4028	0.229	28.23
RC15	NO	-	12/21/84 - 02/18/86	1024.7	6229	0.164	02/18/86 - 02/26/88	1256.3	7630	0.165	0.09
RC15*	NO	-	01/20/83 - 02/06/85	1454.0	9100	0.160	12/21/85 - 02/26/88	1446.4	9464	0.153	-4.35
RC15**	NO	-	01/20/83 - 12/21/85	2057.2	11793	0.174	11/03/86 - 02/26/88	1078.3	6250	0.173	-1.09
RC16	NO	-	01/19/83 - 02/22/85	1296.6	9255	0.140	11/27/85 - 01/05/88	1057.7	8979	0.118	-15.91

CASE #	OCCUP CHANGE	TIMCLK USE	PREVIOUS PERIOD	RAW PREVIOUS gallons	HDD Change	gallons per change in HDD	POST PERIOD	RAW POST gallons	HDD Change	gallons per change in HDD	CHANGE (%)
RC16'	NO	-	01/19/83 - 11/27/85	1588.4	12440	0.128	01/14/87 - 01/05/88	401.9	3659	0.110	-13.98
RC17	NO	-	12/05/84 - 03/07/86	870.5	7108	0.122	03/07/86 - 01/23/88	892.3	6977	0.128	4.43
RC18	NO	-	02/10/83 - 01/04/86	2127.5	13007	0.164	12/09/86 - 03/22/88	1249.9	6018	0.208	26.97
RC19'	NO	-	12/14/84 - 01/04/86	940.8	5643	0.167	03/07/86 - 03/22/88	1661.5	8312	0.200	19.90
RC19	NO	YES	11/14/86 - 01/09/86	849.5	6400	0.133	04/03/86 - 05/06/88	1294.8	8721	0.148	11.85
RC20	NO	-	01/05/83 - 12/20/85	1913.6	13267	0.144	11/29/86 - 02/08/88	748.0	5405	0.138	-4.06
RC20'	NO	-	10/18/84 - 02/22/86	1229.5	7735	0.159	02/22/86 - 04/19/88	1237.9	8977	0.138	-13.24
RC21''	NO	YES	02/25/83 - 12/18/85	1747.7	12342	0.142	11/25/86 - 01/16/88	724.8	4985	0.145	2.67
RC22	NO	NO	02/15/83 - 12/26/85	1549.9	12702	0.122	11/03/86 - 01/16/88	704.8	5370	0.131	7.57
RC23	NO	-	01/13/83 - 12/21/85	1972.2	13156	0.150	12/23/86 - 03/09/88	1066.6	5529	0.193	28.69
RC24	YES	-	02/10/83 - 12/18/85	2276.4	12453	0.183	11/04/86 - 02/24/88	1226.0	6197	0.198	8.23
RC24'	YES	-	11/29/84 - 12/18/85	997.2	5651	0.176	01/05/87 - 01/08/88	801.8	3878	0.207	17.16
WC1	NO	-	01/07/82 - 12/28/83	1683.2	10401	0.162	11/13/84 - 02/19/88	3390.6	18845	0.180	11.18
WC1'	NO	-	02/18/85 - 02/19/86	948.6	5835	0.163	01/20/87 - 02/19/88	1115.2	5738	0.194	19.57
WC1''	NO	-	02/13/82 - 03/18/85	2839.8	17020	0.167	01/16/86 - 02/19/88	2097.6	11157	0.188	12.67
WC2	YES	-	11/10/82 - 12/18/85	1277.3	17523	0.073	11/10/86 - 03/29/88	663.4	8365	0.079	8.81
WC3	NO	-	12/24/84 - 11/20/85	513.0	4979	0.103	02/26/86 - 03/16/88	1137.0	10683	0.106	3.24
WC3'	NO	-	12/26/83 - 04/01/85	863.3	7996	0.108	11/20/85 - 03/16/88	1456.0	13343	0.109	1.06
WC3''	NO	-	12/26/83 - 02/05/85	716.3	6663	0.108	11/20/85 - 03/16/88	1456.0	13343	0.109	1.50
WC4	NO	-	01/22/85 - 11/26/85	219.8	5236	0.042	01/16/86 - 03/31/88	579.9	12008	0.048	15.04
WC5	NO	-	12/15/82 - 02/03/86	1915.4	17803	0.108	01/02/87 - 02/29/88	643.4	6488	0.099	-7.82
WC5'	NO	-	02/04/85 - 02/03/86	621.5	5818	0.107	01/02/87 - 02/29/88	643.4	6488	0.099	-7.17
WC8	NO	-	01/07/85 - 12/31/85	791.2	5868	0.135	02/14/86 - 02/26/88	1459.5	10630	0.137	1.83
WC9	NO	-	01/31/84 - 03/04/85	668.7	6528	0.102	12/09/85 - 02/23/88	1269.9	12257	0.104	1.14
WC9'	NO	-	11/14/84 - 01/20/86	846.8	7772	0.109	12/23/86 - 01/06/88	533.6	5377	0.099	-8.91
WC10	YES	-	02/04/85 - 01/22/86	580.1	5508	0.105	01/22/87 - 03/07/88	634.4	6030	0.105	-0.10
WC11	NO	-	12/29/83 - 02/08/85	558.9	6672	0.084	12/16/85 - 02/19/88	1151.5	11940	0.096	15.13
WC11'	NO	-	12/29/82 - 02/20/86	1590.1	17892	0.089	11/19/86 - 02/19/88	713.4	7309	0.098	9.82
WC11''	NO	-	12/17/84 - 02/20/86	752.8	7645	0.098	11/19/86 - 02/19/88	713.4	7309	0.098	-0.88
WC12	NO	-	01/27/82 - 12/05/83	1159.2	9078	0.128	01/16/86 - 01/08/88	1630.8	10110	0.161	26.33

Appendix C

New Furnaces - Pre/Post Usage, Income, Household Size

	ID	Pre	Post	Change	HHSZ	Income
1.	AR1	0.142	0.087	-38.37	3	15-20k
2.	AR10	0.275	0.251	- 8.72	2	.
3.	AR2	0.230	0.204	-11.49	2	20-25k
4.	AR6	0.159	0.127	-20.16	2	20-25k
5.	AR7	0.221	0.194	-12.34	2	.
6.	AR8	0.076	0.070	- 8.12	3	.
7.	AR9	0.103	0.113	9.99	4	.
8.	CR1	0.137	0.117	-14.57	2	>25k
9.	CR2	0.126	0.094	-25.39	2	.
10.	CR3	0.182	0.181	- 0.31	3	.
11.	CR4	0.426	0.420	- 1.30	1	.
12.	CR5	0.224	0.160	-28.66	2	>25k
13.	CR6	0.149	0.111	-25.75	3	<10k
14.	OR1	0.186	0.153	-17.88	2	>25k
15.	OR4	0.134	0.158	17.86	1	<10k
16.	OR6	0.147	0.121	-17.78	2	10-15k
17.	OR7	0.193	0.162	-16.19	1	10-15k
18.	RR1	0.157	0.096	-38.82	2	20-25k
19.	RR10	0.197	0.213	8.13	2	>25k
20.	RR11	0.078	0.060	-22.97	3	10-15k
21.	RR12	0.137	0.119	-12.80	1	<10k
22.	RR13	0.142	0.141	- 0.72	1	.
23.	RR16	0.156	0.130	-16.27	2	15-20k
24.	RR2	0.119	0.131	9.73	2	>25k
25.	RR20	0.136	0.106	-21.89	2	>25k
26.	RR21	0.082	0.089	8.66	2	.
27.	RR3	0.249	0.169	-32.09	2	10-15k
28.	RR4	0.103	0.143	38.46	1	10-15k
29.	RR5	0.124	0.127	2.27	2	.
30.	RR6	0.122	0.073	-40.41	2	>25k
31.	RR7	0.107	0.095	-11.35	2	.
32.	RR8	0.160	0.114	-28.81	3	20-25k
33.	RR9	0.114	0.096	-15.97	2	15-20k
34.	WR1	0.099	0.132	33.06	2	10-15k
35.	WR2	0.105	0.097	- 8.01	2	.
36.	WR3	0.128	0.127	- 0.70	1	10-15k
37.	WR4	0.135	0.147	9.02	1	<10k
38.	WR5	0.120	0.137	14.04	.	10-15k
39.	WR6	0.113	0.093	-17.65	2	15-20k
40.	WR8	0.118	0.072	-38.90	1	>25k
41.	WR10	0.080	0.087	8.97	1	15-20k
42.	WR11	0.073	0.099	34.75	1	10-15k
43.	WR12	0.085	0.074	-12.80	2	15-20k

Control Cases -- Pre/Post Usage, Income, Household Size

	ID	Pre	Post	Change	HHSZ	Income
1.	AC1	0.062	0.072	16.57	3	>25k
2.	AC1'	0.094	0.079	-15.13	3	>25k
3.	AC2	0.121	0.121	0.35	2	10-15k
4.	AC3	0.140	0.127	- 9.10	3	.
5.	AC4	0.131	0.125	- 4.83	2	>25k
6.	AC4'	0.132	0.124	- 6.34	2	>25k
7.	AC5	0.083	0.089	7.12	2	.
8.	AC5'	0.082	0.108	31.32	2	.
9.	AC6	0.228	0.265	16.18	5	>25k
10.	AC6'	0.215	0.254	18.14	5	>25k
11.	AC7	0.197	0.207	5.14	3	>25k
12.	AC7'	0.204	0.206	0.82	3	>25k
13.	AC7''	0.211	0.206	- 2.33	3	>25k
14.	AC8	0.083	0.102	23.09	2	>25k
15.	AC8'	0.083	0.111	33.93	2	>25k
16.	AC10	0.097	0.123	26.91	1	.
17.	AC10'	0.112	0.135	20.38	1	.
18.	OC3	0.175	0.160	- 8.43	3	>25k
19.	OC6	0.236	0.278	17.67	.	.
20.	OC9	0.189	0.180	- 4.73	2	.
21.	OC10	0.120	0.150	24.19	2	>25k
22.	OC10'	0.122	0.150	22.58	2	20-25k
23.	OC11	0.168	0.188	11.77	1	10-15k
24.	OC12'	0.173	0.180	4.12	1	10-15k
25.	OC12	0.172	0.178	3.56	.	20-25k
26.	OC13	0.328	0.349	6.51	.	20-25k
27.	OC14	0.185	0.218	17.49	2	15-20k
28.	OC14	0.217	0.219	1.03	2	15-20k
29.	OC1	0.100	0.114	13.55	2	.
30.	OC6'	0.219	0.281	28.23	2	>25k
31.	OC8	0.228	0.248	8.61	2	>25k
32.	OC11'	0.167	0.188	12.88	2	20-25k
33.	RC9	0.113	0.093	-17.86	2	20-25k
34.	RC9'	0.085	0.095	11.03	2	20-25k
35.	RC9''	0.085	0.103	21.22	2	20-25k
36.	RC9'''	0.087	0.101	17.05	2	.
37.	RC10	0.212	0.213	0.55	2	.
38.	RC10'	0.185	0.238	28.71	2	.
39.	RC10''	0.184	0.245	33.44	2	.
40.	RC10'''	0.183	0.252	37.60	2	20-25k
41.	RC11	0.144	0.157	9.19	2	20-25k
42.	RC11'	0.142	0.159	11.58	2	20-25k
43.	RC11''	0.144	0.159	10.84	2	20-25k
44.	RC11'''	0.157	0.157	- 0.02	2	>25k
45.	RC12	0.126	0.141	11.56	2	>25k

Control Cases Continued

	ID	Pre	Post	Change	HHSZ	Income
46.	RC12'	0.144	0.135	- 5.75	2	>25k
47.	RC12''	0.132	0.151	14.50	2	>25k
48.	RC12'''	0.138	0.155	11.99	2	<10k
49.	RC13	0.090	0.103	15.53	1	10-15k
50.	RC14	0.202	0.223	10.56	1	10-15k
51.	RC14'	0.203	0.233	14.43	1	10-15k
52.	RC14''	0.191	0.221	15.52	1	10-15k
53.	RC14'''	0.179	0.229	28.23	2	20-25k
54.	RC15	0.164	0.165	0.09	2	20-25k
55.	RC15'	0.160	0.153	- 4.35	2	20-25k
56.	RC15''	0.174	0.173	- 1.09	2	>25k
57.	RC16	0.140	0.118	-15.91	2	>25k
58.	RC16'	0.128	0.110	-13.98	1	.
59.	RC17	0.122	0.128	4.43	1	15-20k
60.	RC18	0.164	0.208	26.97	1	15-20k
61.	RC18'	0.167	0.200	19.90	.	>25k
62.	RC19	0.133	0.148	11.85	.	>25k
63.	RC20	0.144	0.138	- 4.06	2	20-25k
64.	RC20'	0.159	0.138	-13.24	2	20-25k
65.	RC21''	0.142	0.145	2.67	2	.
66.	RC22	0.122	0.131	7.57	2	10-15k
67.	RC23	0.150	0.193	28.69	5	>25k
68.	RC24	0.183	0.198	8.23	3	>25k
69.	RC24'	0.176	0.207	17.16	3	>25k
70.	WC1	0.162	0.180	11.18	2	.
71.	WC1'	0.163	0.194	19.57	2	.
72.	WC1''	0.167	0.188	12.67	2	.
73.	WC2	0.073	0.079	8.81	5	.
74.	WC3	0.103	0.106	3.24	2	>25k
75.	WC3	0.108	0.109	1.06	2	>25k
76.	WC3''	0.108	0.109	1.50	2	>25k
77.	WC4	0.042	0.048	15.04	2	10-15k
78.	WC5	0.108	0.099	- 7.82	5	>25k
79.	WC5'	0.107	0.099	- 7.17	5	>25k
80.	WC8	0.135	0.137	1.83	3	.
81.	WC9	0.102	0.104	1.14	3	.
82.	WC9'	0.109	0.099	- 8.91	1	.
83.	WC10	0.105	0.105	- 0.10	1	.
84.	WC11	0.084	0.096	15.13	1	.
85.	WC11'	0.089	0.098	9.82	1	.
86.	WC11''	0.098	0.098	- 0.88	1	.
87.	WC12	0.128	0.161	26.33	2	.

Appendix D

PROBLEMATIC NEW FURNACE CASES

NEW FURNACE CASES

CASE #	REPLACE DATE	OCCUPANCY CHANGE	TIMCLK USE	TSTAT CHANGE	PREVIOUS PERIOD (before change)	RAW PREVIOUS GALLONS	HDD Change	PRE Gallons per change in DD's	POST PERIOD (after change)	RAW POST GALLONS	HDD Change	POST Gallons per change in DD's	CHANGE (%)
AR12	09/28/84	NO	YES	0	01/04/82 - 06/12/84	635.2	11195	0.057	12/17/84 - 03/17/87	807.6	13448	0.060	5.84
AR13	08/20/85	NO	NO	2	01/11/83 - 04/09/85	1249.4	12949	0.096	10/18/85 - 04/08/88	1325.1	14454	0.092	-4.98
AR14	04/28/85	NO	NO	0	11/11/81 - 06/07/84	870.7	18659	0.064	04/25/85 - 04/07/87	791.4	10618	0.075	16.93
AR15	12/03/85	NO	NO	0	12/21/80 - 05/13/85	2700.4	8779	0.308	12/17/85 - 03/12/87	1746	7381	0.237	-23.10
AR17	03/21/85	NO	YES	0	11/19/82 - 09/06/85	1588.8	13316	0.119	11/04/85 - 03/01/88	1468.6	13610	0.108	-9.56
AR18	01/25/85	NO	NO	0	12/14/82 - 06/25/84	912.0	8400	0.109	01/26/85 - 03/26/87	625.6	12516	0.050	-53.96
AR19	06/20/85	NO	NO	0	11/12/82 - 03/07/85	769.3	13714	0.056	10/03/85 - 03/11/88	818.5	13725	0.060	6.31
AR20	03/06/86	NO	NO	0	11/09/82 - 05/21/85	1756.2	14879	0.118	03/07/86 - 04/27/88	1304.3	11310	0.115	-2.30
AR21	04/20/84	YES	NO	0	12/07/82 - 03/12/84	891.1	7205	0.124	10/02/84 - 04/02/86	957.2	10046	0.095	-22.96
AR22	07/25/86	YES	NO	0	01/02/85 - 04/24/86	620.6	8539	0.073	12/11/86 - 05/05/88	716.7	8206	0.087	20.17
AR23	01/18/85	YES	NO	-3	05/10/84 - 01/15/85	550.8	3339	0.165	01/16/85 - 11/20/85	523.1	4317	0.121	-26.56
AR24	05/16/85	YES	NO	0	09/30/82 - 05/16/85	1896.5	15571	0.122	06/11/85 - 04/19/88	3445.5	15491	0.222	82.61
AR25	10/20/86	NO	YES	0	02/12/85 - 05/08/86	1049.4	7484	0.140	11/10/86 - 03/17/88	875.4	8066	0.109	-22.60
CR9	10/14/86	YES	YES	0	11/12/84 - 03/28/86	1689.7	7945	0.213	11/08/86 - 05/17/88	1423.3	7326	0.194	-8.61
CR11	08/14/85	YES	YES	-3	10/29/82 - 12/20/84	595.9	5112	0.117	12/18/85 - 01/21/88	950.0	8797	0.108	-7.36
CR12	12/04/84	NO	YES	0	12/11/82 - 01/14/84	750.8	4785	0.157	12/06/85 - 01/20/88	1527.2	9321	0.164	4.41
OR9	04/11/86	NO	NO	0	10/08/82 - 05/11/85	522.0	12755	0.041	04/11/86 - 01/11/88	556.7	6407	0.087	112.32
OR10	05/13/86	YES	NO	0	09/28/84 - 04/24/86	1567.0	8594	0.182	05/16/86 - 04/06/88	1582.2	7586	0.209	14.39
OR11	12/11/87	NO	NO	0	9/17/86 - 12/17/87	241.0	5054	0.048	01/18/88 - 05/31/88	394.4	2071	0.190	299.36
OR13	02/11/83	YES	NO	0	10/26/84 - 07/05/86	1264.0	8977	0.141	08/01/86 - 06/01/88	610.1	7993	0.076	-45.79
OR14	02/22/84	NO	YES	0	09/20/82 - 02/07/84	1485.0	6517	0.228	10/01/84 - 04/25/86	1357	9007	0.151	-33.88
OR15	02/23/85	NO	NO	0	04/01/82 - 01/22/85	1140.0	15570	0.073	01/25/85 - 01/27/87	1418.8	9083	0.156	113.34
RR24	02/28/86	NO	NO	0	12/10/83 - 02/05/86	933.1	10875	0.086	06/27/86 - 04/26/88	777.5	7790	0.100	16.32
RR25	05/18/85	YES	NO	0	01/10/83 - 04/15/85	4827.8	10666	0.453	06/14/85 - 11/19/87	4742.4	9333	0.508	12.27
RR26	01/23/85	YES	NO	0	02/01/83 - 12/11/84	1418.5	7428	0.191	01/23/85 - 06/04/86	1374.8	6866	0.200	4.85
RR28	07/18/86	YES	NO	0	12/18/84 - 03/28/86	1370.3	7092	0.193	11/05/86 - 03/15/88	1182	6540	0.181	-6.46
RR30	10/08/86	YES	NO	0	12/27/84 - 03/21/86	912.1	6766	0.135	11/19/86 - 04/11/88	908.7	6706	0.135	0.51
RR33	06/12/85	YES	YES	0	02/02/83 - 03/22/85	1289.0	10068	0.128	10/10/85 - 02/11/88	1748	10770	0.162	26.77
WR13	02/13/85	YES	YES	-3	01/19/82 - 12/27/84	2084.0	15530	0.134	02/21/85 - 04/30/88	2053.8	17475	0.118	-12.42
WR16	03/24/86	YES	YES	0	09/06/84 - 01/19/86	3904.5	8733	0.447	04/01/86 - 05/17/88	3997.6	11129	0.359	-19.66
WR17	07/11/85	NO	YES	5	01/03/84 - 08/13/85	1324.0	8875	0.149	09/09/85 - 03/19/88	1308	14676	0.089	-40.26
WR18	09/30/86	NO	YES	-4	09/14/84 - 06/15/86	664.0	11106	0.060	09/30/86 - 04/08/88	404	9241	0.044	-26.88
WR19	05/30/84	NO	NO	0	10/21/82 - 01/04/84	709.0	6907	0.103	06/20/84 - 04/10/86	866	10663	0.081	-20.88

Appendix D (Continued)

Problematic Replacements: Reasons for Exclusion

NEW FURNACE CASES

CASE #	COMMENTS
AR12	wood heat 50%; gone during winter
AR13	changed furnaces mid-stream
AR14	15% wood
AR15	15% wood
AR17	insulation, st. windows
AR18	1000 sq ft addition in '86; furnace out for long
AR19	30% wood heat
AR20	insulation/new roof
AR21	storm windows @ time of new furn.
AR22	occupancy changes/wood
AR23	insulation/electricity
AR24	remodel w/insulation/occupancy change/50% wood
AR25	remodel w/insulation
CR9	occupancy change/irregular furnace maint.
CR11	occupancy change/attic insulation in '83
CR12	insulation in '84
OR9	gone during heating season
OR10	occupancy change
OR11	extensive remodel/addition
OR13	Insulation, therm. windows, some wood heat
OR14	Insulation, and some wood heat
OR15	large unexplained increase
RR24	remodel/occupancy change
RR25	major occ. change
RR26	occupancy/heated space change
RR28	major occ. change
RR30	heat basement with electric
RR33	occupancy changes/electricity
WR13	occupancy changes
WR16	gone during heating season
WR17	th'pane windows/some elec. heat
WR18	insulation, windows, some elec. heat
WR19	Insulation, strom windows

Appendix E

Energy Efficiency Measures

The three types of "active" measures installed by Oil Help are new furnaces, high efficiency flame retention burners (FRBs), and clock thermostats. The "passive" measures installed are ceiling, floor, and wall insulation. (Duct insulation was also installed in several cases, and asbestos removal was also performed for about 20 furnace jobs, but these measures are not included in the final analysis because savings for them were difficult to calculate and they made up a small percentage of overall rebates and savings.) The vital statistics for these measures are shown in Table 1.

Table 1
Oil Help Measures, Costs, Rebates

Measure	Jobs	Average Cost	Total Measure Cost	% Total Cost	Average Rebate	Measure Rebate	% Total Rebate
New Furnace	1,955	$1,964	$3,838,699	76.9	$513	$1,003,828	77.1
FRB	1,041	642	668,093	13.4	169	175,779	13.5
All Insulation	395	1,137	444,242	8.9	282	111,290	8.6
Clock Therm	439	94	41,087	0.8	24	10,731	0.8
	3,830		4,992,121			1,301,628	

(Most) Active Measures
It is obvious from the table that new furnaces dominate all of the statistics, in terms of number installed, cost, and rebates. The economic calculations for the program are largely driven by the benefits and costs of furnace replacements. Table 2 shows the breakdown on steady state efficiencies for furnaces and flame retention burners (FRBs). The numbers in the last column are used to calculate program savings for furnaces and FRBs.

Table 2
Steady State Efficiency Statistics

Measure	Avg Effic. Before Replacement	Avg Effic. After Replacement	Avg Effic. Change
Furnace	68.9 (N=801)	82.3 (N=82)	16.3 (N=787)
FRB	67.9 (N=652)	81.5 (N=844)	16.6 (N=640)

Program Savings from Furnaces and FRBs
The annual savings calculation for furnaces and burners is based on the change in steady state efficiency of the furnace or burner. This is a controversial approach to estimating savings. There are many changes in a household other than the installation of a new furnace (lifestyle, remodeling, etc.). Over the 2,000 furnace installations, however, we assume that these influences roughly cancel each other out. Based on very preliminary results from our furnace replacement study, we believe the 16.3 percent average savings is close to the upper bound for new furnaces.

Program-wide savings for furnaces and burners thus are as follows:

Furnaces:

$$16.3\% \ \frac{\text{savings}}{\text{furnace}} \times 1{,}955 \text{ furnaces} \times 625 \ \frac{\text{gallons}}{\text{year}} = 199{,}166 \ \frac{\text{gallons}}{\text{year}}$$

FRBs:

$$16.6\% \frac{\text{savings}}{\text{burner}} \times 1{,}041 \text{ burners} \times 625 \frac{\text{gallons}}{\text{year}} = 108{,}004 \frac{\text{gallons}}{\text{year}}$$

Persistence of Savings

A concern about mechanical devices in general is the persistence of energy savings. If a furnace or flame retention burner is not tuned yearly and worn parts are not replaced, it is highly unlikely that it will retain its new steady state efficiency rating. While it is true that most new furnace owners pay for an annual maintenance contract for the first few years of a furnace's life, it is less clear how much longer they pay for annual maintenance. After the thrill of the new furnace has faded, people tend to forget. Their furnace is like their car. As long as it runs and heats the house, all is well. If it does not work, it needs to be fixed. Points in between (i.e., where the furnace is working, but probably less efficiently than when new or just serviced) are not important to many homeowners. Therefore, they may not pay the $75 or so dollars a year (roughly equal to the amount of money saved annually by having a well-maintained furnace of new design) that most oil furnace dealers charge for a service contract.

The implications are substantial. If the furnace savings are less reliable after the first few years, the program will seem a poorer investment over the long term. The economic evaluation of this report looks at only the simple payback of measures and the program, so the long term effects are ignored (an earlier draft calculated life cycle costs, but this approach as scrapped because of the maintenance question). The persistence of savings issue must be remembered when looking at the payback figures.

Clock Thermostats

Based on our survey of the literature, we assume that clock thermostats will save an average of 10% of yearly fuel consumption. This gives a savings contribution from clock thermostats of:

$$10\% \frac{\text{savings}}{\text{device}} \times 439 \text{ clock thermostats} \times 625 \frac{\text{gallons}}{\text{year}} = 27{,}438 \frac{\text{gallons}}{\text{year}}$$

Insulation Issues

Calculation of insulation savings presents some problems. First, we had to deal with the many combinations of measures. R-value changes were all over the map. Then there was the matter of what to do with interactive effects. Duct insulation savings were difficult to calculate. Finally, we had to decide which set point to use in calculating savings. The set point to use in calculating savings. The set point is the outside temperature (used to determine heating degree days) below which the furnace would come on.

A number of simplifying assumptions were used to get around these problems. Insulation was broken down by zone (ceiling, wall, floor) and average areas insulated for each type were used. Weighted averages of the most common R-value (hence UA value) changes were used. Interactive effects were ignored. Duct insulation was dropped from the analysis. (It made up only 7% of insulation rebate money.)

The set point chosen was 60°F. This was seen as reasonable for the Oil Help participants' housing stock after insulation. The more common set point used in analysis of this type has been 65°F; however, after insulation to a "medium" level, houses would be less sensitive to outdoor temperature than before. The 60°F set point also appropriately adjusts savings estimates for those homes in the program which already had or got a clock thermostat which turns off the furnace when the home is unoccupied. If this were not taken into account with the less "sensitive" set point, the effect would be to overestimate savings due to insulation. Using the 65° set point increases the savings for insulation by about 25 percent.

Heating degree days used in the insulation savings calculations are a weighted average of western and eastern Washington heating degree days at base 60°F. We use a 75/25 split, west/east (very close to the actual ratio), which gives a weighted average of 4,150 heating degree days.

Insulation Savings: An Overview

To calculate savings, we use the following equation, based on the standard heat loss equation with no mechanical ventilation (ASHRAE Fundamentals, 1985):

$$F = \frac{24 \times HDD_{60} \times UA}{N \times H}$$

where:

- F = fuel savings (gallons/year)
- HDD = daily heating degree days, base 60°F
- UA = change in UA for different insulation project, given the average area insulated and for different insulation levels.
- N = average pre-retrofit furnace steady state efficiency (68.9% (from Oil Help database)) used in the analysis
- H = energy content of fuel oil (138,690 Btu/gallon)

The procedure is to calculate average percent savings for each type of insulation and then do a weighted average percent savings for all insulation at the end. (The weights used will be rebate dollars by insulation type as a percentage of all insulation rebate dollars.)

Ceiling Insulation Savings

For this type of insulation, we assume 2 X 8 framing with 24" oc. The technique used for assigning thermal resistances for ceiling components is found in the 1981 ASHRAE Fundamentals, page 23.23.

About 2/3 of the jobs resulted in an R-value change from R-11 to R-38 (U = 0.026). The average job for this category was 900 ft^2. The other 1/3 had an R-value change from R-4 to R-38 (U = 0.178). The average job for this category was 1,240 ft^2. The corresponding weighted average for UA is then given by

$$2/3 \times \frac{900\ ft^2 \times 0.026\ Btu}{°F \times ft^2 \times hr} + 1/3 \times \frac{1{,}240\ ft^2 \times 0.178\ Btu}{°F \times ft^2 \times hr} = 89.1 \frac{Btu}{°F \times hr}$$

Therefore:

$$F = \frac{24\ hr \times 4{,}150°}{68.9\% \times 138{,}690 \frac{Btu}{gallon}} \times \frac{89.1\ Btu}{yr\ °F \times hr} = 92.9\ \text{gallons/year/job}$$

Assuming 625 gallons per year average oil consumption, the 92.9 gallons amounts to 14.9 percent average savings for a ceiling insulation job.

Wall Insulation Savings

All walls done by Oil Help go from uninsulated to R-11. According to the 1981 ASHRAE Fundamentals, for 2 X 4 framing, this would mean a U of 0.125. The average wall insulation job is 800 ft^2. The UA is then equal to 100 $\frac{Btu}{°F \times hr}$.

Therefore:

$$F = \frac{24\ hr \times 4{,}150°}{68.9\% \times 138{,}690 \frac{Btu}{gallon}} \times \frac{100\ Btu}{yr\ °F \times hr} = 104\ \text{gallons/year/job}$$

Assuming 625 gallons per year average oil consumption, the 104 gallons amounts to 16.7 percent average savings for a wall insulation job.

Floor Insulation Savings

All floors go from uninsulated to R-19. About 1/3 of the cases involve unheated basements (U = 0.086; average job is 704 ft^2) and 2/3 are unventilated crawlspaces (U = 0.157; average job is 1,190 ft^2). This gives a weighted average for UA of $\frac{145 \text{ Btu}}{{}^{o}F \times hr}$.

Therefore:

$$F = \frac{24 \text{ hr} \times 4{,}150^{o}}{68.9\% \times 138{,}690 \frac{\text{Btu}}{\text{gallon}}} \times \frac{145 \text{ Btu}}{{}^{o}F \times hr \times yr} = 151 \text{ gallons/year/job}$$

Assuming 625 gallons per year average oil consumption, the 151 gallons amounts to 24.1 percent average savings for a wall insulation job.

Overall Insulation Savings

The total rebates for insulation, not counting duct insulation, were $103,201 as of the end of August. The three insulation types' relative percentage of this money is as follows:

Ceiling insulation:	53%
Wall insulation:	22%
Floor insulation:	25%

These will be the weights in the overall savings calculation:

Categorical insulation savings =

$$0.53 \times 14.9\% + 0.22 \times 16.7\% + 0.25 \times 24.1\% = 17.6\%$$

This gives annual savings of 17.6% X 625 gal X 395 cases = 43,450 gallons/per year

Table 3

Program-Wide Benefits and Induced Savings

Measure	Annual Gallons Saved	Annual $ Savings ($0.85/gal)	Measure Payback Years
New Furnace	199,166	$169,291	22.7
FRB	108,004	91,803	7.3
Insulation	43,450	36,933	12.0
Total	378,057	$321,348	
Program Payback			16.7

(Program overhead of $380,000 (two years included))

END

DATE FILMED

6/01/92